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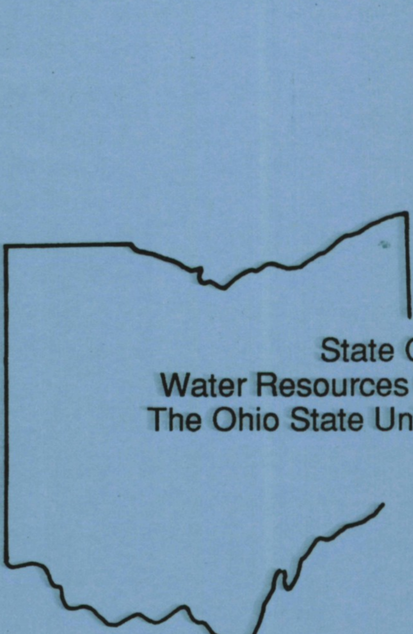
Report No. G-2039

FISCAL YEAR 1991 PROGRAM REPORT

Robert C. Stiefel
Director

United States
Geological Survey



State Of Ohio
Water Resources Center
The Ohio State University

Report No.
G-2039

Fiscal Year 1991 Program Report

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for

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Geological Survey

by

Water Resources Center
The Ohio State University
Columbus, Ohio 43210

Robert C. Stiefel, Director

September, 1992

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ABSTRACT

Most of Ohio's water problems are associated with water quality. Of primary concern are the sediments, nutrients and acids in the surface waters from urban, agricultural and mining areas, and the toxic and hazardous wastes that threaten the ground and surface waters. The focus of the 1991 State Water Research Program was directed at these areas. The research and technology transfer program consisted of the following activities: The technology transfer programs of the Water Resources Center continue to disseminate information about the water resources of Ohio to the local and state decision-makers, and provides technical assistance to help resolve some of the state's major water problems. One project was an oceanographic dynamics study, for Lake Erie, which used mathmatical models to calculate how contaminant loading from rivers will interact with the Great Lakes Forecasting System. This project will provide accurate and timely loading figures for the forecasting system. The hydrologics project by Steven G. Buchberger, studied alternate wastewater treatment and technologies using wetlands. The groundwater remediation project studied hydrophobic organic compounds (HOC) which are in groundwater systems and strongly sorbed by soil organic matter. This study characaterized the effects of chemical additives (co-solvents) in an effort to enhance HOC mobility in groundwater systems. The fate and transport project studied the dynamic features of pesticide-degrading microorganisms as they relate to changes in the redox speciation of their environment. A water quality project by Dr. Susan Fisher, studied how pesticides survive in water and how long they remain active in water.

Training on these research projects was provided to eleven students from six disciplines at two universities. These include six M.S. students in the areas of Agronomy (2), Environmental Engineering (1), Entomology (2) and Microbiology (1): two Ph.D. students in the disciplines of Civil Engineering and Geology and a Post-Ph.D. in Environmental Science. In addition, two undergraduate students, one in Agronomy and the other in Environmental Science gained practical knowledge and training by working on these projects.

TABLE OF CONTENTS

Water Problems and Issues of Ohio

Water is one of Ohio's most important natural resources. Bounded on the north by Lake Erie and on the south by the Ohio River and containing other extensive ground and surface waters, Ohio has an adequate supply of water to meet its immediate needs. However, the combination of large, heavily industrialized urban centers; extensive agricultural activities; high volume coal production and large coal reserves; and the associated demands for new energy production continues to cause concerns related to water quality and water management. In addition, extreme hydrologic events cause localized problems of both excessive water and water deficiencies at times.

Surface Water

The northern 25 percent of Ohio's area drains into Lake Erie, while the southern portion drains into the Ohio River. Runoff from Ohio's streams and rivers averages about 25 billion gallons per day. The state also receives nearly a billion gallons of runoff daily which drains through the Maumee River to Lake Erie from the neighboring state of Indiana; and Ohio has access to additional flows past its boundaries in Lake Erie and the Ohio River that total well over 150 billion gallons of water per day.

Last year, more than 16 billion gallons of water were withdrawn from Ohio's surface sources each day to meet the demands for municipal supplies; rural needs for domestic and livestock purposes; irrigation; and self-supplied industrial needs including cooling water for thermo-electric power generation. These demands account for only 60 percent of the available surface waters in the state's streams each day, and localized shortages only develop during certain dry seasons and periodic droughts.

The combined length of all the streams in Ohio approaches 44,000 miles, which means that there is approximately one mile of stream for each square mile of surface area in the state. In addition, there are more than 50,000 lakes, ponds and reservoirs within the state having a combined surface area of 200,000 acres. Only a small fraction of these, about 6,700 acres, occur naturally. The remainder are man-made impoundments that range in size from small farm ponds to large multipurpose reservoirs.

The reservoirs in the state are used to provide water for many different purposes including municipal, agricultural and industrial supplies; stream flow augmentation; flood control; and recreation. No impoundments in Ohio, other than those on the main stem of the Ohio River, provide water for downstream navigation or hydro-electric power generation. However, there is extensive navigation on both Lake Erie and the Ohio River, and consideration is being given to the installation of low-head hydro-electric generators at several developed dam sites throughout the state.

Flooding, still a major problem in Ohio, affects both urban and agricultural areas; and it has been estimated that nearly two million acres of land in Ohio are flood prone. This represents over seven percent of the total area of the state and includes nearly four percent of those areas classified as urban regions. Average annual flood damages in Ohio vary from year-to-year but amount to several millions of dollars annually.

Ground Water

Ground water is an important part of Ohio's water resources. Ground water underlies most of the state but is predominant in the glacial drift in the northwest, in the ice-contact and outwash deposits in river valleys along the border of the glaciated areas, and in the bedrock of the western portions of the state. Ground water supplies are largest in the glacial valley-train deposits in those drainage basins which border the Ohio River including the Ohio, Miami, Little Miami, Scioto, Hocking and Muskingum Rivers. Well yields from these deposits often exceed 500 gallons per minute (gpm), while aquifers in the glacial drift in the northwest and west-central parts of the state produce yields between 100 and 500 gpm. Isolated aquifers in the northeast, northwest and southwest have yields between 25 and 200 gpm, while much of the northeast contains aquifers whose yield is between 5 and

25 gpm. With the exception of the valleys along the major streams, most of the aquifers in the area that is tributary to the Ohio River have yields less than 5 gpm.

Three-quarters of Ohio's 650 public water supply systems use ground water as their source. In terms of volume withdrawn, however, a lesser share of these supplies comes from ground water, for only around a half billion gallons of ground water are withdrawn each day for public water supply purposes, while over one billion gallons come from surface water sources. However, ground water supplies nearly 80 percent of the rural water needs in Ohio, 32 percent of the irrigation waters and 21 percent of the industrial water demands. Nearly one billion gallons of ground water are withdrawn in the state each day to meet these needs.

Water Quality

It is the quality of water, rather than its quantity, that is the more critical and limiting condition associated with the use of both ground and surface waters in Ohio. The ground waters of the state frequently have relatively high, natural mineral contents; but, except for a few local areas, most of these waters are free from man-related contamination. Most complaints are related to increased levels of turbidity, bacterial populations and other substances from improperly sited or poorly constructed or maintained wells. Other problems are related to the spillage and leakage of brines and petroleum at oil wells in the southeastern part of the state; the mis-application of pesticides, herbicides and insecticides in agricultural areas; and the improper siting and operation of solid and liquid waste disposal facilities. Some minor ground water problems associated with the excessive use of highway de-icing salts or its improper storage have also been reported.

The dissolved solids concentrations in Ohio's streams range between 120 and 2,500 milligrams per liter (mg/l). The higher concentrations are found in the Tuscarawas, Cuyahoga and Grand Rivers and in other stream reaches below major municipal and industrial outfalls or in areas subjected to diffuse source runoff.

Of the 23,000 miles of the principal rivers downstream of major urban areas in the state that have been monitored, 16,000 miles, or 70 per cent of these streams, meet the current water quality standards. Where problems do exist, they are frequently caused by inadequate municipal wastewater treatment at facilities that need be upgraded or expanded, or by combined sewer overflows.Substantial improvements in surface water quality have resulted from the development of pretreatment regulations for industrial waste discharges to municipal sewerage systems. Violations of the state's water quality standards occur most often in dissolved oxygen levels; ammonia nitrogen concentrations; the numbers of fecal coliforms; and the levels of heavy metals such as lead, zinc, and cadmium.

Acid mine drainage is a major cause of water quality problems throughout the Appalachian Coal Basin in the eastern United States. In Ohio this region extends in a band approximately 50 miles wide in a southwesterly direction from the east-central to the south-central parts of the state. Acid drainage from abandoned and improperly operated or reclaimed coal mined lands causes a loss of water for domestic and industrial uses; the degradation of water quality for recreational purposes; a lethal impact on the aquatic life in a stream; and an accelerated deterioration of highway and railroad bridges and electrical transmission lines and towers. Drainage from abandoned coal mines, both surface and underground, has impacted around 1,500 miles of streams in 27 counties in southeastern Ohio. Approximately 370,000 acres of abandoned strip mines, 7,000 acres of coal refuse piles and 3,000 underground mines are contributing to this problem. It has been estimated that four billion dollars would be needed to reclaim the abandoned mines and refuse piles throughout Ohio. Projected revenues from severance taxes earmarked for abandoned mine reclamation come to about ten million dollars annually. Obviously, the technologic problems and the economic costs associated with the control of acid mine drainage will continue to keep this a major problem of water quality in southeastern Ohio for years to come.

Little detailed information is available concerning the impacts that diffuse sources of pollution such as agricultural and urban stormwater drainage have on the quality of water in Ohio's inland streams. One concern with non-point pollution is the sediment that is dislodged from the land surface and carried to the streams. Of greater concern are the pollutants, such as the nutrients, heavy metals and toxic organic substances, that enter the streams attached to the sediments. No need for intensive, non-point source control programs to meet water quality standards in that area of the state that drains to the Ohio River has been shown; but several studies are underway in the Lake Erie drainage basin to define the role of agricultural drainage on the water quality in the lake. Much more research and many more demonstration projects on the best management practices for agriculture, silviculture, mining and urban runoff control must be conducted before this problem is fully understood and control measures can be instituted.

The trophic status of several lakes and reservoirs has been studied; and the results suggest that the lakes and reservoirs in the sandstone bedrock areas of the state have generally lower trophic levels than those in the limestone bedrock areas or glaciated regions. Water quality was generally good to excellent in most of the lakes and reservoirs surveyed. However, excessive concentrations of copper and other heavy metals, bacteria and other pollutants normally associated with urban activities were identified in some of the lakes. Recent studies on Lake Erie indicate that there has been a reduction in several key pollutants and a gradual, but steady, improvement in the water quality in the Lake during the past few years. Phosphorus is a major pollutant which results in the excessive growth of algae and other aquatic plants. As these plants die and decay, they deplete the oxygen resources of the Lake. The construction of faciliites to remove phosphorus at those municipal wastewater treatment plants which discharge directly to Lake Erie has been a major factor in the reduction of phosphorus loadings and of the subsequent reduction of the anoxic areas within the Lake. Additional work on the control of phosphorus from both diffuse sources and point sources needs be accomplished, but a significant start has been made.

Levels of bacteria have been reduced in the nearshore zones where municipal wastewater treatment facilities have been constructed. This has permitted regulatory agencies to re-open bathing beaches which were often closed during the period between 1960 and 1970. Concentrations of mercury and pesticides have been reduced substantially, principally because of the federal bans that have been instituted on their manufacture, use and disposal. PCB remains a major challenge, as does the control of sediment and the nutrients, fertilizers and organic chemicals that are attached to it.

Fish populations, including the walleye pike, are beginning to increase again in the lake; but the quality and diversity of fish is still far from what they were in the past. Thermal pollution is a localized problem in some near-shore areas. However, as closed cycle cooling is required on all power generation facilities, the extent of this problem will diminish.

PROGRAM GOALS AND PRIORITIES

The Water Resources Center at The Ohio State University encourages and supports research that is directed at providing information needed to solve the major water problems at the local, state, regional and national levels. The research program at the Center includes basic or fundamental research, problem oriented or applied research, and information dissemin- ation and technology transfer activities.

During FY 1982, the Center, in cooperation with several groups of water-related agencies and officials throughout the State prepared a prioritized list of Ohio's major water resources problems. Based upon this analysis, the following ranking of these problems was developed:

1. **POLLUTION FROM DIFFUSE SOURCES** - including agricultural runoff; urban runoff; runoff from on-site waste disposal systems; runoff from active, reclaimed or abandoned coal and strip mines.

2. **CONTAMINATION OF DRINKING WATER SUPPLIES** - including surface and ground waters for both urban and rural uses by diffuse and point sources, and by the disposal of toxic and hazardous wastes on the land.

3. **TOXIC AND HAZARDOUS WASTE DISPOSAL** - including their control, treatment, disposal and impact upon land, water and air resources.

4. **POLLUTION FROM POINT SOURCES** - including municipal and industrial sources not yet in compliance with their NPDES permits.

5. **IMPACTS OF FLOODING AND DRAINAGE** - including flood damages, the use of flood plains and alternative structural and non-structural means of controlling floods and reducing flood damages.

6. **IMPACTS OF WATER RESOURCES DEVELOPMENTS** - including the impacts on various developments such as the extension of water mains and sewers into rural areas; flood control projects; hydro-electric power generation; water -based recreation; etc.

7. **INSTREAM FLOWS NEEDS** - including interrelationships among water quality, water quantity and land use practices on the instream flow needs for fish, wildlife, recreation and the optimum development and protection of these instream uses.

8. **IMPACTS OF SYNTHETIC FUEL DEVELOPMENT** - including requirements for water and impacts of the disposal of wastes from these processes into water and onto the land.

9. **IMPACTS OF ATMOSPHERIC POLLUTION** - including the effects of acid precipitation and atmospheric fallout on water quality and the environment.

10. **ALLOCATION OF WATER RESOURCES**- including the development of contingency plans for the allocation and conservation of limited water supplies among competing water users during periods of low stream flows.

Subsequently, the Directors of the Water Resources Research Institutes in the Great Lakes, Upper Mississippi and Ohio River Basin's met to identify from their State problems the major water resources research priorities for the Region. A listing of these priorities is included at the end of this Section of this Report.

The focus of the 1991 State Water Resources Research Program was primarily directed at some of these critical needs. The research and technology transfer program consisted of the following activities: The technology transfer programs of the Water Resources Center continue to disseminate information about the water resources of Ohio to the local and state decision-makers, and provides technical assistance to help resolve some of the state's major water problems.

The project by Keith W. Bedford was an oceanographic dynamics study, using mathmatical models to calculate how contaminant loading from rivers will interact with the Great Lakes Forecasting System. This project entitled "The Real -time Forecasting of Great Lakes Tributary Loads and Impacts Resulting from Storms and Other Extreme Events, will provide accurate and timely loading figures for the study.

The report by Steven G. Buchberger, "Simulation of Constructed Wetlands for Treating Wastewater studied alternate wastewater treatment and technologies using wetlands. This hydrologic study of wetlands used mathematical models to describe and simulate transient variable water contaminant movement at constructed wetlands.

The groundwater remediation project by Franklin W. Schwartz, "Co-Solvent Processes in Aquifer Remediation" studied hydrophobic organic compounds (HOC) which are in groundwater systems and strongly sorbed by soil organic matter. This study characterized the effects of chemical additives (co-solvents) in an effort to enhance HOC mobility in groundwater systems.

The fate and transport project by Samuel J. Traina , "Effects of Redox-Induced Chemical Gradients on the Sorption-Biodegration of Pesticides at Colloid-Water Interfaces", studied the dynamic features of pesticide-degrading microorganisms as they relate to changes in the redox speciation of their environment. The specific objectives were to deterime the effect of steady-state redox gradients on the sorption of selected pesticides to natural and model soils and sediments; to determine the effect of steady-state redox gradients on the biodegration of selected pesticides; and to determine the effect of steady-state redox gradients on sorption/desorption of selected pesticides as related to biodegradation processes.

A water quality project by Dr. Susan Fisher, studied how pesticides survive in water and how long they remain active in water. She used the Molecular Connectivity indices for this research.

Technology transfer program continued to work closely with the water professionals locally, state-wide and nationally in cooperative efforts, jointly sponsored programs and newsletter and reports.

SYNOPSIS

Project Number: 02 — Start: 07/01/91 (actual)
End: 06/30/93 (expected)

Title: The Real Time Forecasting of Great Lakes Tributary Loads and Impacts Resulting from Storms and Other Extreme Events

Principal Investigators: Keith W. Bedford, The Ohio State University

COWRR: 02H — Congressional District: Fifteenth

Descriptors: transports, forecasting, tributary loading, numerical modeling, Great Lakes

Problems and research objectives: Nonpoint source watershed runoff from agricultural lands is especially aggravated during storms. With storms occurring roughly every seven to ten days in Ohio (Irish and Platzman 1962), the resulting delivery of these runoff pollutant products to the tributaries, and ultimately the Great Lakes (Erie), is a continuous series of sharp impulsive loads to the Lake. The storm driven loads often occur very quickly, coinciding with the maximum tributary discharges, while the post-storm recession is stretched over time as pollutants are slowly released back to the tributaries from flooded wetlands, etc. In determining the ultimate load to the Lake it is also necessary to account for the effects of strong stratification and water level fluctuations at the confluence of the Lake (Bedford and Mark, 1988) as well as the re-suspension and transport of in-place pollutants occupying the harbor regions at these confluences (Lee and Bedford 1987b). The International Joint Commission (IJC) has designated over forty highly polluted Areas of Concern (AOC), some six of which are the major tributaries draining to Lake Erie. A consortium of International Joint Commission, USEPA, Canadian Ministry of the Environment and USGS bureaus is charged with the responsibility of estimating these loads to the Great Lakes on a monthly basis. These agencies then in turn must use these data to implement water quality management decisions and remediation plans. The currently used operational load estimation procedure is based upon monthly average estimates based on empirically adjusted data collected quite far upstream at USGS monitoring sites. These sites are well upstream of the Lake confluence. The Maumee River gauge is over 30 km upstream. The data collected are so far upstream that all the AOC effects are ignored and one month averaging horizons effectively preclude resolution of the impulsive, spiky nature of the loading. In essence then accurate loading estimates are not available; the magnitudes are heavily misestimated and transformations within the downstream tributary/Lake mixing zone in the AOCs are unaccounted for. The result is poor water quality management.

Methodology. The verticle plane modeling technology has been adapted to the Maumee River (Podber, 1991) and evaluated with known data on the interactions of flow reversal and stratification (Podber and Bedford 1992)., as the first step in this two year project. Various combinations of the major factors affecting loading have been tested. These factors include tributary and receiving water temperatures, river transport and stage, lake oscillations and river basin bathymetry (silled and unsilled) The modeling strategy is predicted on the tributaries being relatively narrow and long which (Bedford 1989) for Lake Erie is the case for all tributaries except Sandusky Bay. As noted in the 1989 article all these confluences exhibit significant interactions between vertical stratification and internal and surface long period oscillations which impede Lakeward transport (Bedford and Mark 1988) and must be accounted for in the model.

Predictions of the horizontal and vertical velocity are made as well as predictions on temperature and passive tracer/contaminant. A terrain following coordinates system is used which allows full resolution of bathymetry and channel geometry features. While this model is used in the dredged channel portions, water level and flow calculations between the upper end of the dredged channel and the operational gaging station will be done using the one-dimensional Dynamic Water Quality Model (Bedford et al., 1982) which is now the model in use for all such calculations by the US Army Corps. of Engineers (1989).

Principal Findings and Significance: The major .accomplishment to date is the construction and testing of the numerical model. Under a start up grant (Grant PAS705-1) given by the Ohio Supercomputer Center, the numerical model briefly described above has been written and tested. The preliminary results have been published in a master's thesis and reported to the scientific community at a professional conference (see information transfer activities sheet). The significance of this accomplishment is that the questions concerning the accuracy of loading estimates can now be addressed. The creation and adaption of the numerical model for the Maumee River is essential for the accomplishment of the goals in this project. The fact that this code is viable and computer resources are available means that; 1) nowcasts can be performed, 2) integration into the Lake Erie Information Forecasting System (LEIFS) can be executed so that predictions of river stage can be made from the Maumee River and river inputs can be supplied to the LEIFS, 3) loading estimates can be computed from the numerical model for comparison with figures given to water quality management agencies.

The range of test cases that have been examined to date are the eight possible combinations associated with three major factors thought to be important: silled or unsilled bathymetry, spring or autumn temperature conditions, and strong or weak river flow. For each of these cases a complete calculation was made that extended over several 14 hour seiche periods. A horizontal resolution of 250 meters combined with 20 vertical slices to create a very fine level of detail in the calculation. The advantage of such a detailed vertical resolution is that density and st ratification effects are better approximated with high vertical resolution. These density effects are central to exchange between an estuary and its receiving waters. The calculation included the Mellor and Yamada level 2.5 turbulence closure scheme to account for the vertical mixing of water properties. This scheme is currently accepted by the fluid dynamics community as a standard approach. The Mellor and Yamada scheme includes the effects of density variations on mixing, this feature is essential to properly model the physics in the mixing zone. The numerical code also makes use of a bottom following, or sigma coordinate system. This transformation increases the complexity of the equations that describe fluid motion, but provide an advantage by simplifying the implementation of boundary conditions and by increasing the portability of the model, namely that the code is easily adapted to model other Great Lakes Tributaries.

This type of numerical model is a quite sophisticated tool, and it has to be in order to tackle the complex issues and feedbacks associated with mixing zone (estuarine) dynamics. By better understanding these dynamics, the pressing needs of water quality and water management can become more scientific and more effective.

<u>Dissertations</u>: Podber, David Paul, 1991, "Modeling Great Lakes Tributary Flow and Transport," M.S. Thesis, CIvil Engineering Department, The Ohio State University, pp.125.

<u>Conference Proceedings:</u> Podber, David P. and Keith W. Bedford, 1992, "Modeling Great Lakes Tributary Flow and Transport," International Association of Great Lakes Research Conference, Waterloo, Ontario.

SYNOPSIS

Project Number: 03 | Start: 07/91 (actual)
End: 06/91(expected)

Title: Simulation of Constructed Wetlands for Treating Wastewater.

Investigator: Buchberger, Steven G., University of Cincinnati

COWRR: 05B   Congressional District: First and Second

Descriptors: constructed wetlands, wastewater treatment, hydrologic fluxes, monte carlo simulation

Problem and Research Objectives: Wastewater treatment technology has espoused a proliferation of concrete and steel facilities in the United States over the past 70 years. Escalating energy requirements and increasing labor costs have generated economic pressures to develop other more cost effective yet environmentally sound ways to control water pollution. The search for alternate treatment technologies has led to the rediscovery of natural wastewater treatment systems.Natural systems achieve wastewater treatment by exploiting the physical, chemical and biological processes that ordinarily occur within a plant-soil-water matrix. In contrast to conventional concrete and steel treatment facilities which require continuous operation of complex energy intensive mechanical equipment, natural treatment systems are designed to minimize the need for artificial controls. In addition, there is another very important distinction between natural systems and conventional treatment facilities. Natural treatment systems interact strongly with the atmosphere. The performance of a natural treatment system is significantly affected by rainfall, evaporation and temperature. Because these hydrologic fluxes change over time, natural treatment systems do not operate as a steady-state process.

Use of natural wastewater treatment systems will increase in the future. Optimal design and operation of natural systems are hindered, however, by a lack of understanding regarding complex biological, chemical and physical processes that regulate natural systems and by a poor representation of dynamic hydrologic mechanisms affecting treatment performance. This has led to imprecise design and operating criteria which promote expedient and over-simplified solutions at the expense of efficient and cost effective natural wastewater treatment systems.

The objective of this research is to synthesize and test a mathematical model which describes and simulates transient, spatially variable water and contaminant movement at constructed wetlands. The emphasis is on developing an improved understanding of how key hydrologic processes (including evaporation, precipitation, infiltration, temperature) affect wetland performance. New insights gained from this study will be used to formulate a rational risk-based approach for sizing constructed wetlands for treating wastewater.

Methodology: Conceptual Approach: Wetland treatment capability changes continuously during the course of a year with highest efficiencies achieved during warm summer months. One way to exploit the seasonal performance of a wetlands is to recycle effluent whenever discharge concentrations exceed regulatory standards. It is assumed, therefore, that the constructed wetlands can be represented as a lined continuously stirred tank reactor (CSTR) followed by a lined plug flow reactor (PFR) that recycles, if necessary, back to the CSTR. The PFR is the primary device for wastewater treatment. While some treatment will occur in the CSTR, its chief purpose is to equalize flow by storing incoming wastewater and collecting recycled effluent whenever the PFR is unable to achieve desired levels of treatment.

Design Objectives: Now the problem of wetlands design amounts to finding the minimum surface area and embankment height of the CSTR and the minimum treatment area of the PFR to assure that effluent concentrations comply with regulatory standards. A probabilistic standard will be adopted here. For instance, the standard might require that effluent BOD concentrations not exceed 10 mg/l at least 95 percent of the time.

Process Simulation: The wetlands simulation model requires simultaneous solution of the hydrodynamic equations (continuity and momentum) for water flow and the mass balance equations for dissolved constituents in a CSTR and a PFR. Since the treatment system is subject to non-stationary hydrologic fluxes (waste loading, evaporation, precipitation, energy), the solution involves Monte Carlo simulation imbedded in a numerical solution scheme. An hourly time step will be used to model wetland performance.

Key steps include:

(1) Specify hydraulic flow regime parameters and initial conditions.
(2) Simulate temperatures, evaporation, precipitation, and first-order reaction rates.
(3) Solve hydrodynamic equations for depth and the flow along the PFR.
(4) Use results from steps (2) and (3) to compute effluent concentrations along the PFR.
(5) Determine whether or not the final effluent concentration from the PFR meets the water quality standard; if a violation occurs and if the running number of violations exceeds the permissible count, then recycle effluent back to the CSTR.
(6) Generate mass loadings to the CSTR.
(7) Determine the new depth of wastewater and new concentrations in the CSTR.
(8) Repeat steps (2)-(7) to simulate many years of hourly wetland operation.
(9) Produce frequency distribution of concentrations in PFR and depths in CSTR.
(10) Estimate reliability-based size of CSTR from distribution of wastewater depths.

Design Optimization: Here the goal is to identify the least cost design that complies with effluent discharge standards from feasible CSTR-PFR combinations. This essentially amounts to running the Monte Carlo simulation enough times to identify a minimum point or region on the wetland cost (size) response surface.

Model Application: The design procedure will be applied to two case studies at existing constructed wetlands located in humid and arid regions of the United States.

Principal Findings and Significance: Research progress is on schedule and on budget. This project is running concurrently with a wetlands design project sponsored by the US Department of Energy. Our literature review on constructed wetlands has examined over 100 papers and reports. We have visited experimental wetlands facilities at Tennessee Technological University and full-scale constructed wetlands operating in Pembroke, Hardin and Benton, Kentucky. We are scheduled to make two presentations at the upcoming International Wetland Conference in Columbus in September 1992. The source code for the movement of water and the transport of contaminants through free water surface wetlands has been developed and verified. We are linking this source code with program modules that simulate hourly precipitation and hourly wastewater loading.

This project represents the first attempt to formulate the design of natural treatment systems in terms of transient spatially variable stochastic hydrologic fluxes that affect wetland performance. This work will provide a more realistic description than is presently available of water and contaminant movement through natural treatment systems and lead to a better understanding of how key hydrologic factors impact the performance and integrity of natural wastewater treatment systems. Since parameter and process uncertainty are incorporated directly into the design phase, results of this work will provide a sound scientific approach for generating acceptable reliability-based alternatives from which optimal (least cost) solutions can be identified. This design approach will generate cost effective alternatives having high probabilities of meeting regulatory requirements and hence improve current deterministic methods for designing natural treatment systems.

SYNOPSIS

Project Number: 04 | Start: 09/91 (actual)
End: 06/31/92 (expected)

Title: Co-solvent Processes in Aquifer Remediation

Investigators: Schwartz, Franklin W. and Chin, Yu-Ping, The Ohio State University, Columbus , Ohio

COWWR Category: 04B | Congressional District: Fifteenth

Descriptors: groundwater, contaminant, remediation, column, solvent, displacement

Problem and Research objectives: In this study, we are characterizing the effects of co-solvents in an effort to enhance LNAPL mobility in groundwater systems. Predicting the effects of miscible solvents on sorption can be modeled using the following equation

$$\log_{K_{occs}} = \log K_{ocw} - {}^{\alpha\sigma}f_{cs} \qquad (1)$$

where K_{occs} and K_{ocw} are the organic carbon normalized partition coefficients of the binary solvent and water respectively, α is an empirical constant, σ is the solvency potential, and f_{cs} is the fraction of co-solvent in the aqueous phase (Rao et al., 1985; Fu and Luthy, 1986). Reliable values of σ are not well documented in the literature, and we report here a fast and precise reverse phase high performance liquid chromatography (RPHPLC) method for determining σ.

Methodology: RPHPLC retention times for individual compounds in co-solvent mixtures (for this study methanol/water) are measured using a C_{18} reverse phase column. The analyte capacity factor, k' (a normalized retention time) is used to determine the partitioning behavior of the analytes in the presence of co-solvents

$$\log k' = \log k_w - {}^{\alpha\sigma}f_{cs} \qquad (2)$$

where k_w is the retention time of the compound in pure water. For RPHPLC stationary interactions α is assumed to be one (Woodburn et al., 1986), although our data indicates a value of α of 1.1 (Table 1).

In RPHPLC column experiments, a mobile phase comprised of a precise methanol/water mixture was pumped through a C_{18} reverse phase column (NOVA-PAK) and into a detector (fluorescence or UV/VIS absorbance) that is specific to the analyte. Acetone was added to the sample matrix as an internal standard and measures the mobile phase retention time. We examined the elution behavior of 15 nonpolar contaminants using methanol concentrations that ranged from 65 to 90 percent by volume (Table 1).

Soil batch equilibrium experiments are being conducted to verify RPHPLC estimates of K_{occs} for three polycyclic aromatic hydrocarbons (2-methylnaphthalene, phenanthrene, and pyrene) using equation 1 and our RPHPLC derived σ values. Values for α were taken from the literature and vary from 0.500 (Fu and Luthy, 1986) to 0.921 (Karickhoff, 1984). Soil batch experiments consist of soil; buffered water solution with varying amounts of methanol to determine the effects of co-solvents; and µL spikes of target compounds in a 50 mL centrifuge tube. The soils were obtained from Rossburg, Ohio, from the Ohio MSEA site in Piketon, Ohio, and from Florida (University of Florida - P.S.C. Rao). These soils provide a wide range of f_{oc} values for both aquifer and soil systems. Every batch experiment is comprised of seven sample tubes containing soil and different concentrations of a compound; seven control tubes containing respective varying concentrations of the compound; and a blank containing soil and buffered water solution only. After the tubes are spiked with a contaminant, the tubes were wrapped in alunimum foil to prevent photodegradation and were placed on a shaker at constant temperature until equilibrium was reached (~48 hours). The tubes were next centrifuged for one hour at 23° C and 2000 rpm (~1000 g) and then assayed on a spectrofluorometer (SLM-Aminco SPF-500) to determine equilibrium concentrations.

Alcohols that are completely miscible in aqueous systems are chosen as co-solvents due to the efficiency of alcohols in reducing the partition coefficients of compounds. In an aquifer co-solvent flushing system, a series of floods containing water and a small percentage of alcohol could effectively remove contaminants down to target levels after only a few pore volumes (Figure 1). A series of floods which used water only would flush any remaining alcohol from the system. Residual alcohol (ppm - ppb) could be biodegraded quickly and easily.

Principal findings and significance: RPHPLC column results indicate an excellent correlation between the capacity factor and the fraction percent of methanol (figure 2). RPHPLC yielded σ values for the - fifteen aromatic compounds under investigation are in good agreement with literature values determined by other methods (Table 1).

Batch experiment results show a pronounced effect on the sorption of three polycyclic aromatic compounds (2-methylnaphthalene, phenanthrene, pyrene) by a silty soil in the presence of co-solvents. A four to five-fold increase in the solution phase concentration of our analytes was observed as the methanol concentration was increased from 0 percent to 30 percent by volume , and this was accurately predicted using the above model when the value of a was set at 0.5 (Figure 3a, 3b, and 3c). Solvency potential values elucidated from batch studies are comparable to those determined by RPHPLC and other techniques (Figure 4).

Soil sorption rate experiments using phenanthrene in varying methanol/water solutions are currently being performed in order to determine the effect of co-solvents on sorption/desorption kinetics. Preliminary data show an increase in the sorption rate with increasing co-solvent composition. Our results appear to corroborate observations made by Brusseau and co-workers (1991) for the sorption/desorption of HOCs in soil columns.

The results from this research will be submitted to appropriate scientific journals for publication. The published results will be beneficial to other researchers studying the effects of co-solvents; to environmental planners remediating groundwater systems contaminated with LNAPLS; and to researchers and modelers studying the characteristics of multicomponent contaminant spills/sources.

TABLE 1 : Compounds to be evaluated in co-solvent aquifer study.

	Compound	log K_{ow}	σ (batch)	σ (literature)	σ(RPHLC)*
1.	Alpha-Naphthol	2.00		3.01**	3.63 (3.30)
2.	Anthracene	4.54		4.21*-4.96	4.59 (4.17)
3.	Benzene	2.11		2.06*	3.15 (2.86)
4.	Biphenyl	4.09		3.97*	4.37 (3.97)
5.	Ethylbenzene	3.15			3.88 (3.53)
6.	Fluorene	4.18		3.60†	4.43 (4.03)
7.	Mesitylene	3.60			4.25 (3.88)
8.	Methylnapthalene	4.11	3.93		4.27 (3.88)
9.	Naphthalene	3.36		1.83 † - 3.79**	3.63 (3.30)
10.	Para-Xylene	3.15			3.87 (3.52)
11.	Pentamethylbenzene	4.63			4.70 (4.27)
12.	Phenanthrene	4.57	4.53	3.31* - 4.28†††	4.50 (4.09)
13.	Pyrene	5.18	4.29	4.30*- 4.93†††	4.76 (4.33)
14.	Tetramethylbenzene	4.11			4.43 (4.03)
15.	Toulene	2.69			3.46 (3.15)

* for $\alpha = 1.0$ ($\alpha = 1.1$)
* Morris et al., 1988; † Lane and Loehr, 1992; ** Fu and Luthy, 1986; †† Wood et al., 1990; ††† Pinal et al., 1990

Figure 1
Comparison Between theTraditional and Our Enhanced Pump-and-treat

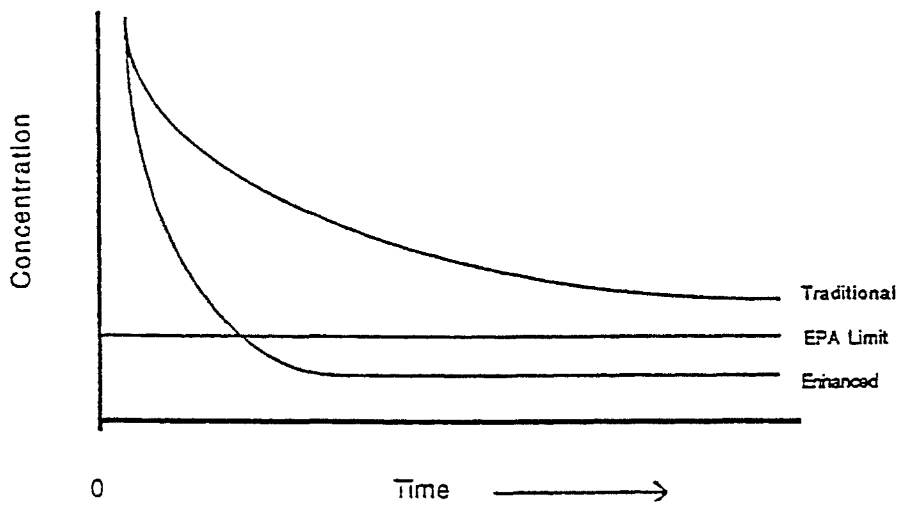


Figure 3a
Co-solvent (Methanol) Effects on the Sorption of Methylnaphthalene
by Rossburg, Ohio Soil

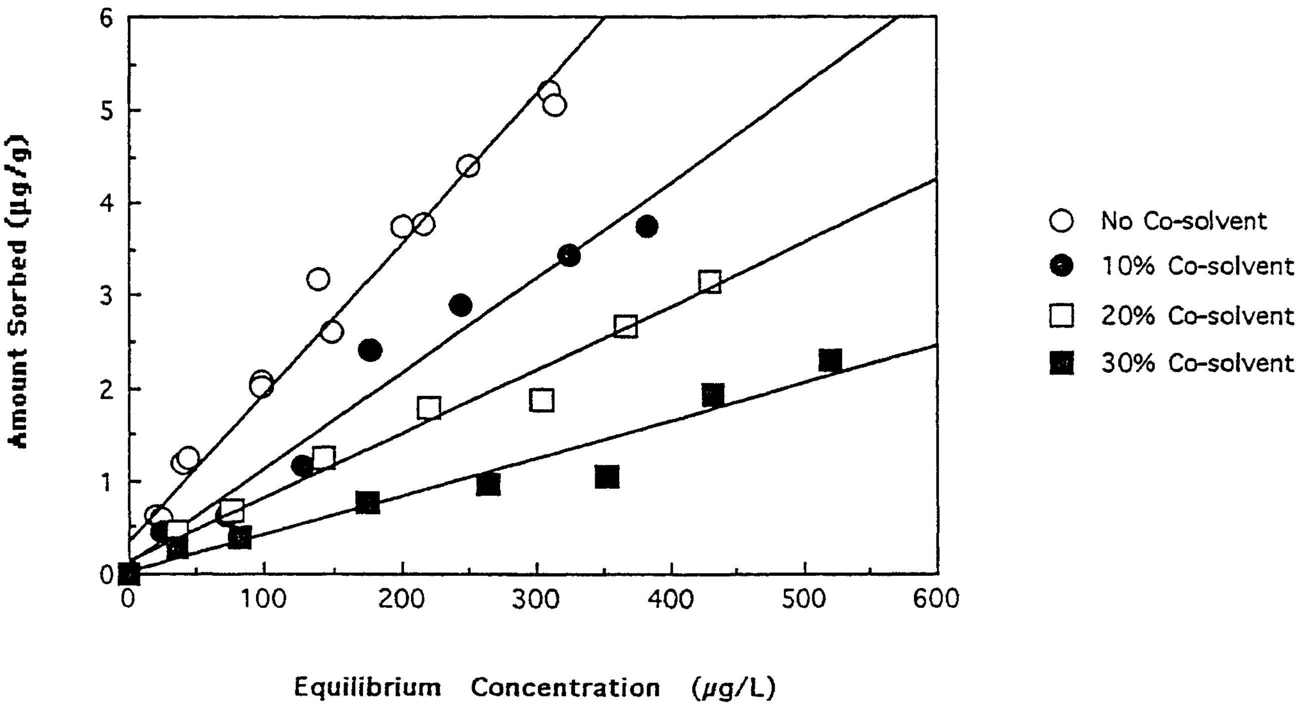


Figure 2
Co-solvent (Methanol) Effects on the Capacity Factor for Three Polycyclic Aromatic Hydrocarbons

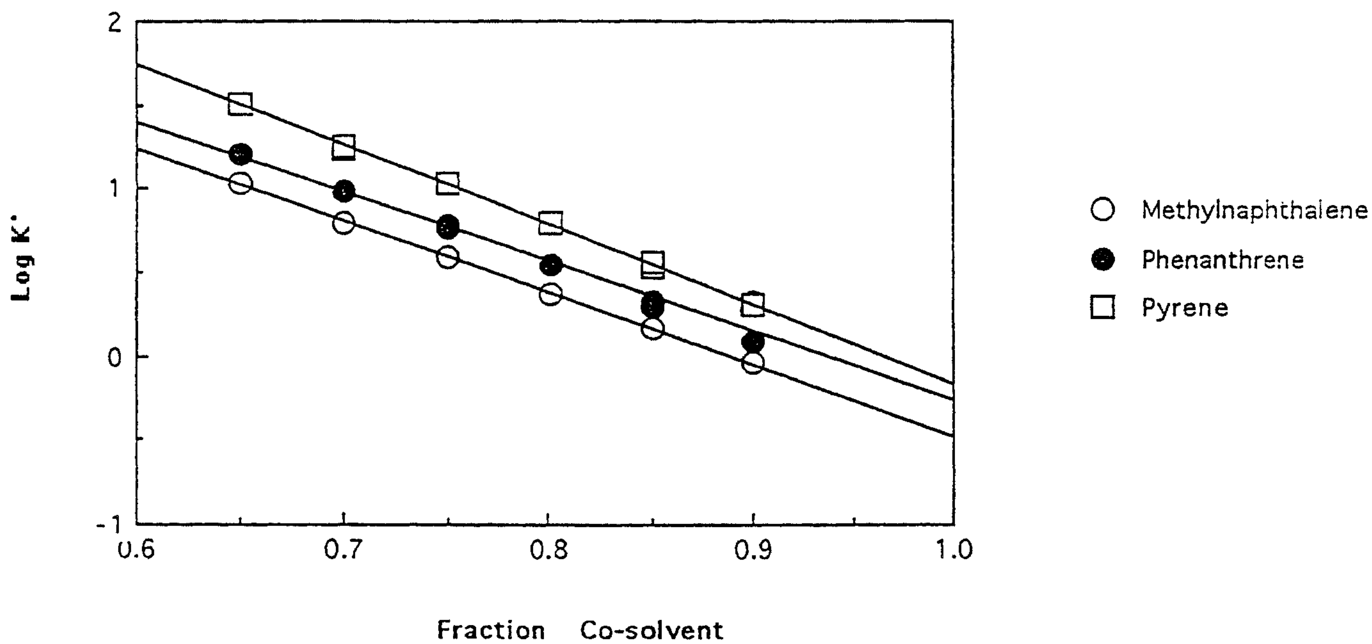


Figure 3b
Co-solvent (Methanol) Effects on the Sorption of Phenanthrene
by Rossburg, Ohio Soil

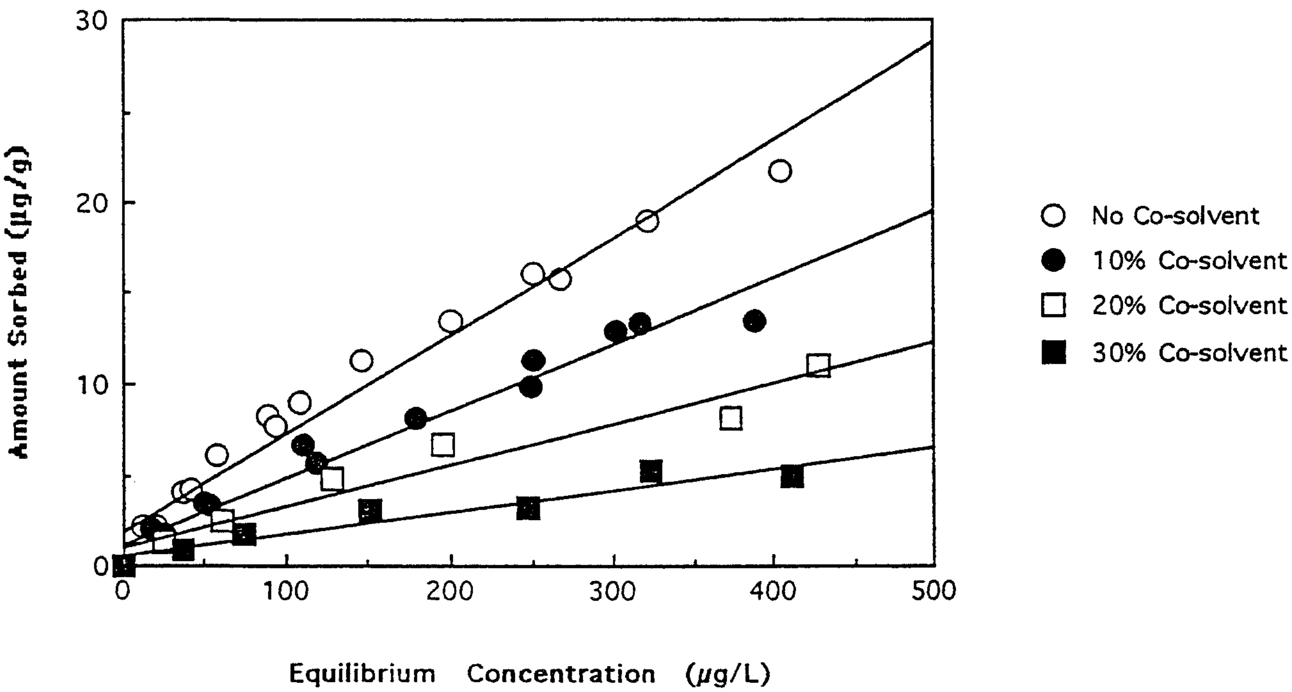


Figure 3c
Co-solvent (Methanol) Effects on the Sorption of Pyrene
by Rossburg, Ohio Soil

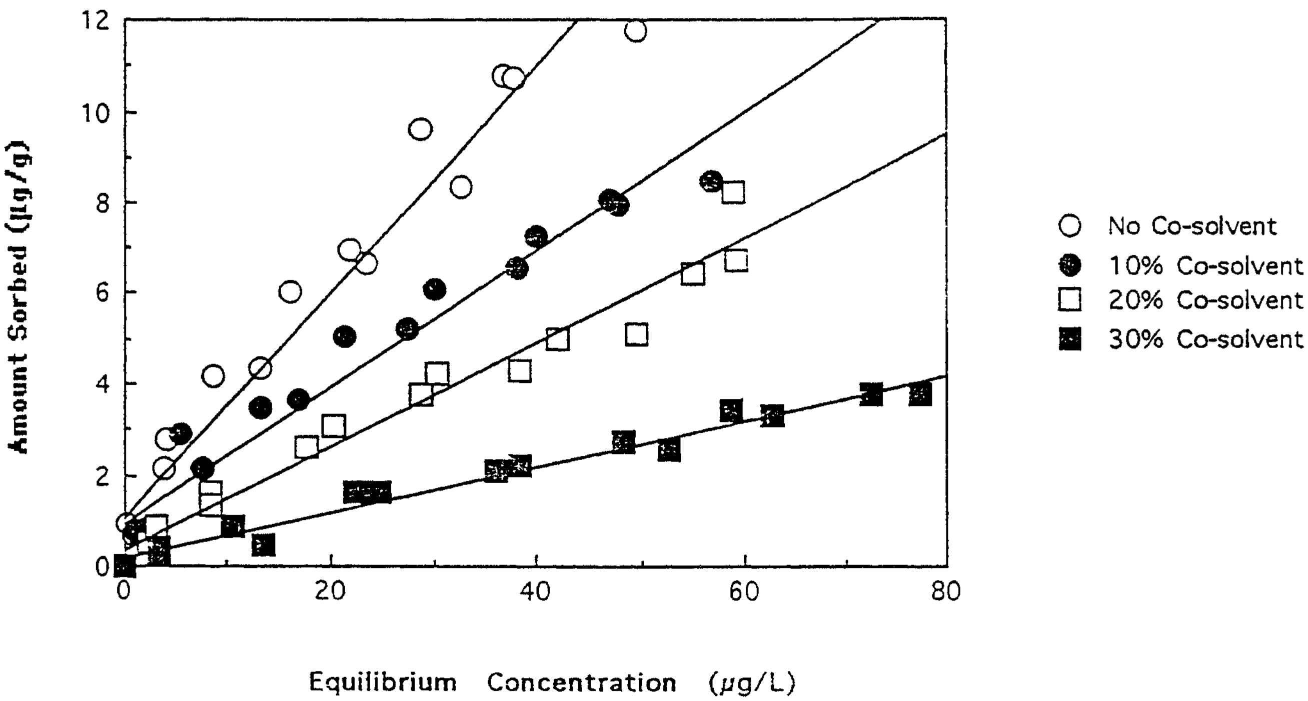
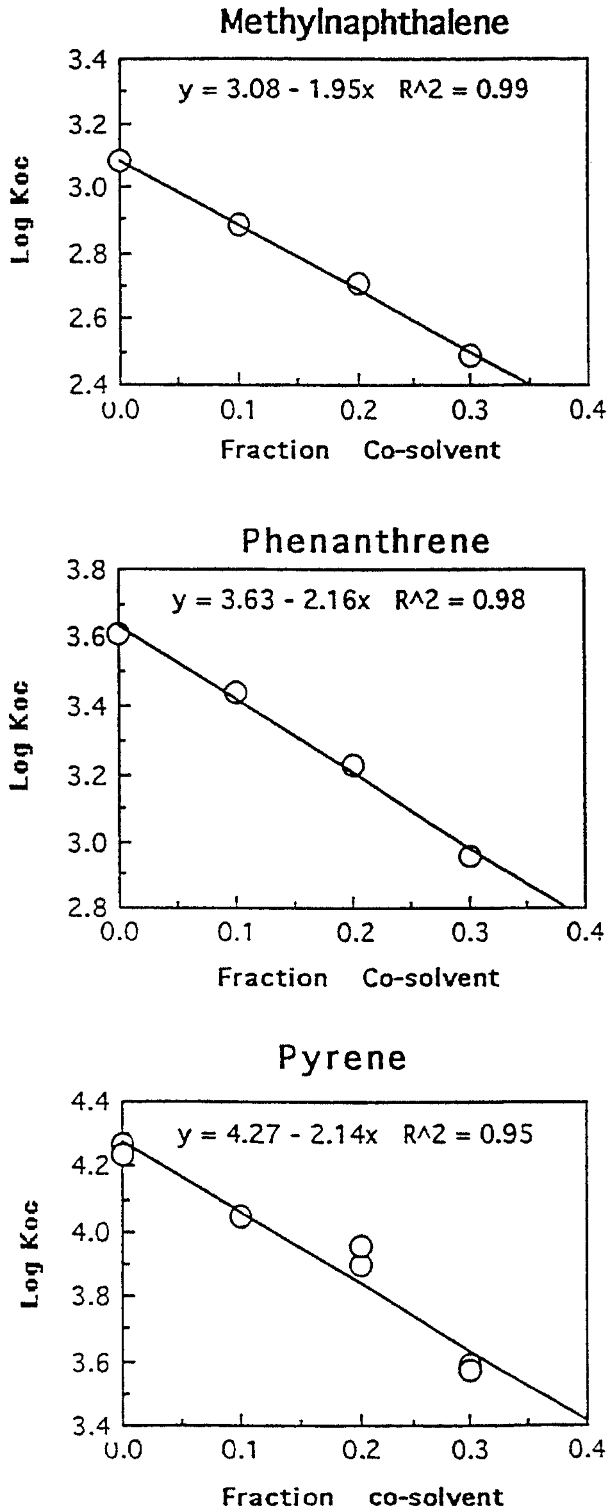


Figure 4
Effect of Co-solvent (Methanol) on the
Partition Coefficient (Batch Experiments)



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Wood, A. L., Bouchard, D.C., Brusseau, M.L., and Rao, P.S.C. 1990. Cosolvent effects on sorption and mobility of organic contaminants in soils. Chemosphere. V.21, N. 4-5.

SYNOPSIS

Project Number: 05 Start: 06/91 (actual)
End: 06/93 (expected)

Title: Effects of redox-induced chemical gradients on the sorption-biodegradation of pesticides at colloid-water interfaces

Investigators: Dr. Samuel J. Traina and Dr. Olli H. Tuovinen, The Ohio State University

COWRR: 05B Congressional District: Fifteenth

Problem and Research Objectives:

The contamination of the nation's surface and groundwater aquifers by pesticides represents a problem of regional and national significance. This problem calls for the development of accurate models which can predict the fate of these compounds in natural waters. Clearly, a complete and thorough understanding of the interactions between chemical and biological processes is required to predict the persistence of pesticides. The proposed work will seek to characterize the dynamic features of pesticide-degrading microorganisms as they relate to changes in the redox speciation of their environment. It is the interfacial natural environment, spanning from highly oxidized to increasingly reduced conditions, that usually is the setting for biological degradative processes. It is the biodegradation potential associated with microorganisms in this redox-controlled, dynamic natural environment and the effects of redox on linked sorption-biodegradation reactions that we propose to elucidate in this work. Natural aquatic environments are characterized by interfaces which commonly involve dynamic oxidation-reduction (redox) gradients concurrent with gradients in pH, dissolved oxygen, carbon dioxide, nitrate, sulfate, and numerous other aqueous species. These gradients occur in sediments and bottom layers of surface waters as well as in groundwater aquifers. Gradients with dynamic changes in redox species and microbial activities can also be found in subsurface cores. Microbiological processes in interfacial environments range from aerobic respiration (oxygen as the electron acceptor) to highly reducing activities involving ferric iron reduction, denitrification, sulfate reduction, and ultimately methane formation. At present, there is no information available to evaluate the microbiological degradation of pesticides under conditions that occur in interfacial redox gradients. Dissolved oxygen, availability of anaerobic electron acceptors, and the redox potential of the environment are the major features that regulate microbial activities in such environments. The aerobic degradation of many pesticides has been extensively documented in the literature. Recent data on a few selected pesticides also demonstrate at least partial microbial degradation under highly reduced conditions as observed under methanogenesis, but it is not known how these limited data can be extrapolated to other ambient redox conditions. Neither is it fully understood how redox status affects pesticide sorption, yet it is now apparent that sorption strongly influences the biodegradation of pesticides. This present lack of fundamental information restricts the development of accurate, mechanistic models of the fate and transport of pesticides in surface and subsurface soils, sediments and natural waters. The proposed research will redress this problem by examining the effects of redox on the sorption and biodegradation of pesticides at colloid-water interfaces. The results will enable us to predict the pattern of pesticide degradation in dynamic, natural environments characterized by stratification phenomena (particularly redox) and a high degree of interaction at the level of microorganisms and particulate materials. Information from these studies will be useful in evaluating the persistence of pesticides especially in confined aquifers and in sediment-water interfacial layers. There are little previous experimental data on the fate of pesticides in interfacial, redox-dominated environments. The results of this study will greatly facilitate future efforts in the development of kinetic models to predict the fate of agricultural chemicals in groundwater environments. Additionally, this information will be useful in evaluating the complexity of factors that determine the fate of other xenobiotic compounds in confined environments. The specific research objectives are concerned with a series of laboratory experiments which will examine the effects of steady-state redox gradients on the coupled sorption and biodegradation of selected pesticides, simulating interfacial and subsurface environments:

1. To determine the effect of steady-state redox gradients on the sorption of selected pesticides to natural and model soils and sediments.

2. To determine the effect of steady-state redox gradients on the biodegradation of selected pesticides.

3. To determine the effect of steady-state redox gradients on sorption/desorption of selected pesticides as related to biodegradation processes.

Methodology: Test materials Sediment and soil samples were obtained from selected sites in Ohio, including the MSEA study site in Piketon. These materials were used to obtain indigenous bacteria capable of degrading the pesticides alachlor and atrazine under denitrifying conditions and alachlor under sulfate reducing conditions. Additionally, a reference culture of the sulfate reducer *Desulfomonile tiedjei* was obtained for studies on anaerobic dehalogenation of 3-chlorobenzene in redox gradient environments.

Degradation experiments. The biodegradation of atrazine alachlor and 3-chlorobenzene, and their respective metabolites has been monitored with HPLC. Aerobic degradation experiments have been carried in standard shake flasks. Anaerobic experiments were conducted in 100 ml serum vials capped with butyl-rubber septa. These were filled with degassed culture media and sparged with He prior to sealing or filled in an anaerobic hood. Culture media typically consisted of Cl-free salts. Denitrifying cultures contained NO_3- salts and sulfur reducing cultures, SO_4^{2-} salts. To date the majority of the biodegradation experiments have been conducted in solution culture (no substrate adsorbing sediments). A typical biodegradation experiment consist of inoculating a solution containing the appropriate electron acceptor and the substrate of interest (as either a C, N, or C and N source) and then following the loss of parent compound and the production of metabolites over time. In some experiments, dehalogenation was confirmed by measuring the release of C^{l-} ion to solution with a Cl-titrator. Principal findings and significance: Degradation of 3-chlorobenzene: The transformation of 3-chlorobenzene (3-cb) to benzoate by *Desulfominile tiedjei* was confirmed under sulfate reducing conditions. A *Psuedomonad* culture was obtained from a mixed sediment and soil sample which can degrade the metabolite of 3-cb, benzoate under aerobic and denitrifying conditions. This will allow us to construct a consortia within a redox gradient created in semi-solid augar. It is anticipated that the bottom of the gradient will be under sulfur reducing conditions while the top will be under aerobic to denitrifying conditions. Inoculation of this gradient with these two organisms will allow us to meet the redox-biodegradation objectives of this study. Alachlor degradation: The anaerobic degradation of alachlor was studied under fermentative, denitrifying and sulfate reducing conditions. Alachlor served as either the sole C and N, C or N source. The sulfate reducing culture showed a 50 percent loss of alachor relative to the control and the denitrifying culture showed a 90 percent loss of alachlor relative to the control, after 31 days. No attempts were made to measure dehalogenation, nor were any specific metabolites identified. The composition of these bacterial cultures has yet to be determined.

Atrazine degradation: A pure culture, tentatively identified as *Agrobacterium radiobacter* was isolated from soil samples obtained from the Western branch agricultural experiment station of the Ohio State University. This organism was found to degrade atrazine and cyuranic acid (an atrazine metabolite). Initial evidence indicates that this organism can utilize atrazine as its sole C and N source. Dehalogenation has been confirmed by release of Cl^- to solution. Whereas, it does degrade atrazine under denitrifying conditions, the degradation rate is much less than in aerobic environments. No attempts have been made to measure dehalogenation under anaerobic conditions. Obtaining these cultures provides us with a range of organisms and compounds with which to study the effects of redox on sorption-biodegradation interactions. The work that we will conduct in the second year will indicate how these processes interact in the natural environment.

SYNOSIS

Project No. 06

Start: 7/91 (actual)
End: 6/92 (actual)

Title: Prediction of Surface Water Contamination by Pesticides

Principal Investigator: S. W. Fisher, The Ohio State University, Columbus, OH

COWRR: 05B Congressional District: Fifteenth

Descriptors: surface water, contamination, pesticides, sediment, fate, prediction

Problem and Objectives:

Under the revised Ohio Pesticide Law, the development of predictive parameters for estimating the fate of cholinergic pesticides such as the carbamates and organophosphorus insecticides is mandated. This task is formidable since such pesticides are not long-lived and may disappear even though the biological effects of exposure continue. In addition, the stability and toxicity of these pesticides are strongly affected by environmental variables such as pH, temperature and sediment type. The objectives of this research were to develop and evaluate a variety of predictive parameters for their ability to forecast the hazard posed by cholinergic pesticides under different environmental conditions. Various biological endpoints including LC50s and I50s of each chemical to the 4th instar larvae of the midge. *Chironomus riparius,* were measured as was the physical stability of each chemical under different pH and temperature regimes. Then the ability of both one-dimensional and multidimensional molecular descriptors to describe changes in toxicity and/or stability was assessed using regression analysis.

Methodology. The toxicity of each chemical to 4th instar midge larvae was estimated in water alone and water with sediment using the method of Lydy *et al.* (1990). The amount of insecticide necessary to inhibit 50 percent of the nervous system enzyme, AChE, was measured using the colorimetric method of Ellman (1961). Linear solvation energies for each chemical were calculated according to the method of Kamlet *et al.* (1986); molecular connectivity indices were calculated using the method of Hickey and Passino-Reader (1991).

Principal Findings and Significance: The toxicity of a series of 12 organphosphorus and carbamate insect ides was measured against the midge in sstems with and without sediment. Five molecular descriptors (Molecular Volume (MV)), Henry's Law Constant (HLC), n-octanol/water partition coefficient (K_{ow}), Molecular Connectivity (MC) and Linear Solvation Energy (LSE)) were used in regression analysis as potential predictors of insecticidal activity. The regressions were conducted for each descriptor against toxicity values for the series of chemicals in aquatic systems with and without sediment.

MV and HLC showed no relationship with toxicity. However, Log K_{ow} was moderately successful in describing the effect of sediment on toxicity (r^2 =0.508). Prediction of toxicity was substantially improved by using LSE and MC in regressions. In multiple regressions conducted on carbamates and organophosphorus insecticides separately, these two parameters explained up to 95.8 percent of the variability in toxicity. Based on the results of regression analyses, sorptive interactions between insecticides and sediment appear to exert a dominant influence on toxicity when sediment is present. In the absence of sediment, the regressions suggest that the structure of the molecule is more important than solubility or partitioning in determining toxicity.

The potential of the 12 insecticides to inhibit the nervous system enzyme, acetylcholine esterase (AChE) was measured *in viro* in the midge at three temperatures: 10, 20 and 30°C. I50 and ki values were calculated and regressed against all five molecular descriptors previously described. Regressions were performed at each temperature to determine if the descriptors were capable of accounting for shifts in inhibition due to changing environmental conditions.

MV, HLC and Log K_{ow} showed no relationship with either I50 of ki at any temperature. The use of MC and LSE relationships in regression analyses greatly improved prediction. A combination of MC or LSE parameters against organophosphorus and carbamate inhibition data yielded correlation coefficients as high as 99 percent. MC gave the best results supporting the hypothesis that interactions between inhibitor and the active site are the most important factors in determing enzyme inhibition.

From these data, we conclude that multidimensional descriptors such as MC and LSE are complex enough to provide information on the many complex processes which ultimately produce a toxic response in the midge. The one-dimensional parameters used in this study did not describe the biological or physical nature of the chemicals well enough to be useful in the prediction of insecticide fate. While the multidimensional descriptors did not characterize specific functional groups, they may be useful in pointing out which properties of each molecule contribute to toxicity and thus point to additional one-dimensional descriptors that could be used to estimate fate and toxicity.

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Publications:

1. Articles in Referreed Scientific Journals

Fisher, S. W., M . J. Lydy, J. Berger and P. F. Landrum (1992). Quantitative Structure-Activity Relationships for Predicting the Toxicity of Pesticides in Aquatic Systems with Sediment. In Press, Environmental Toxicology and Chemistry.

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Information Transfer Activities

The Water Resources Center is housed in the Agricultural Engineering Building on The Ohio State University campus. This location provides daily opportunities to work closely and share ideas with researchers in the College of Agriculture as well as the College of Engineering . It also provides a close working relationship with the OSU Agricultural Engineering Cooperative Extension Service. A series of tasks were continued or initiated to transfer and disseminate information developed by researchers affiliated with the Water Resources Center to a wide range of State, Federal, County and Municipal agencies; to the private sector, to the academic community and to provate citizens throughout Ohio.

WATER LUNCHEON SEMINARS

The Water Resources Center continued to co-sponsor bi-monthly Water Luncheon Seminar Programs for the water resources community in Central Ohio. These programs, are developed cooperatively with The Ohio Department of Natural Resources (ODNR), the Ohio Environmental Protection Agency (OEPA), the Soil Conservation Service (SCS), the District Office of the United States Geological Survey (USGS), and the Cooperative Extension Service of The Ohio State University. They continue to attract more than 350 water resources professionals annually from Federal, State, County and Municipal Agencies, the private sector and the academic community. These seminars provide a forum to discuss current state, federal and local water policy issues, problems, programs and research results. In addition to providing speakers for one meeting a year, the Water Resources Center provides the administrative and financial support for the seminars. The Center also provides technical equipment to assist the speakers with their presentations. The programs which were presented during the series follow.

WATER LUNCHEON SEMINAR FY 1991

Date	Speaker/ (Sponsoring Agency)	Topic
September 10, 1991	Ms. Jennifer Tiell, Chief Div. Emergency & Remedial Response (Ohio EPA)	Ohio's Hazardous Waste & Remedial Response Program
November 14, 1991	Mr. Jerry Wager Admin. Pollution Abatement Section (Ohio Dept. Natural Resources)	The Non-Point Pollution Solution Process
January 21, 1992	Dr. Berlie Schmidt Soil Scientist & Water Quality Program Manager (Water Resources Center & MESA Project)	U. S. Department of Agriculture - Cooperative State Research Service Water Quality Research
March 17, 1992	Dr. William Elliot Assistant Professor Soil & Water Conservation Engineering (OSU Cooperative Extension Service)	Soil Erosion Prediction Technology: WEPP
May 19, 1992	Mr. Stephen G. Jordan Project Director Big Darby Creek (U.S. Geological Survey)	The Nature Conservancy An Overview of Ohio Projects

INFORMATION DISSEMINATION ACTIVITIES

The Center continued meeting with the leading water resources officials in the state for the purposes of sharing information on current water management and policy issues; seeking continued support for our water research program and disseminating the information and technology developed through this program and others at the universities throughout the state and region.

The Center, continued publishing its quarterly newsletter "WATER" which focuses on Ohio's water research, technology, issues, legislation in process, education and Center activities. This publication has a wide circulation that includes public officials, water managers throughout Ohio, university researchers in Ohio and throughout the nation, as well as the general public. It has been well received. Mrs. Carol Moody, is the editor for the newsletter and the secretary to the Center.

WATER MANAGEMENT ASSOCIATION OF OHIO (WMAO)

The Water Resources Center continued to be the communications center for the WMAO. This not-for-profit, 300 member, state-wide organzation promotes and supports the development, conservation, control, protection and utilization of the water resouces of Ohio for all beneficial purposes. It is the only Ohio organization that is solely concerned with managing Ohio's water. The WRC provides staff support, office space and equipment to WMAO as a portion of the information transfer program.

OHIO WATER ATLAS

The Center has continued discussions with the Ohio Department of Natural Resources, the Ohio Environmental Protection Agency, other state agencies and universities to develop a Water Atlas for Ohio.

COOPERATIVE ARRANGEMENTS

Program Development

A call for pre-proposals for the Fiscal Year 1991 State Water Resources Research Program was mailed to research administrators and qualified faculty investigators at more than 40 private and public colleges and universities throughout Ohio in mid-November, 1990. This announcement contained the research priorities identified for the major water problems in the Great Lakes, Upper Mississippi and Ohio River Basins by the Water Resources Research Institutes in the Region.

The announcement also required interested researchers to request a copy of the Preliminary Proposal Application Form which was to be completed and returned to the Water Resources Center in late January, 1991.

Pre-Proposals/Federal Guidelines

Preliminary Proposal Application Forms were requested by and sent to nineteen investigators and research administrators at eight colleges and universities in Ohio. One of these colleges responding was Central State University, an Historically Black University, although they did not submit a pre-proposal application for inclusion in the 1991 selection process. In addition to the application form, a list of the federal guidelines for the Program was also enclosed.

Evaluation/Selection Procedures

Eleven pre-proposals from five universities and colleges throughout the state were submitted for evaluation and consideration. The pre-proposals were subjected to a review by all of the members of the Water Resources Center's Advisory Committee. In addition, these pare-proposals were distributed to the various divisions within the four principal state and federal water-related agencies in the State by the representatives of these agencies who serve on the Advisory Committee, requesting that the divisions review the proposals. The four agencies included in this evaluation were the Ohio Department of Natural Resources, the Ohio Environmental Protection Agency, the District Office of the United States Geological Survey and the Agricultural Research Service in the United States Department of Agriculture.

The results of these reviews were presented at a meeting of the Advisory Committee where this panel selected seven of the pre-proposals and instructed the Center's Director to request fully developed proposals from the investigators for the Committee's further considered.

The seven selected pre-proposals were developed more fully and were re-submitted for consideration. The proposals were subjected to a technical review by at least three qualified evaluators selected by individual members of the Water Resources Center's Advisory Committee. many of these evaluators were from state and federal agencies or from the Battelle Memorial Institute.

The results of these reviews were presented at a meeting of the Advisory Committee and this panel ranked the leading proposals in the order they felt would best meet the needs and objectives of the Water Resources Center's program. The Advisory Committee then instructed the Center's Director to incorporate as many of these projects as Federal funds would permit into the FY 1991 Program, and to develop a project for information transfer for the Center. there was enough Federal monies to support five projects.

The membership of the Water Resources Center's Advisory Committee, which includes representatives from five colleges and eleven departments of The Ohio State University and representatives of the three principal water-related state and federal agencies is included in this report.

Regional Cooperative Initiatives

The five projects selected for this program were compared with the FY 1991 Program synopsis of the projects included in the programs of the other Water Resources Institutes in the Great Lakes, Upper Mississippi and Ohio River Basin to ensure that there was no duplication of efforts in the Region's research programs.

The Ohio State University has agreed to continue as a Charter Member of the Ohio River Basin Research and Education Consortium, and the Director of the Water Resources Center will continue to serve as one of the University's three representatives to the Consortium.

The Director has been appointed by the Governor of the State of Ohio to serve on the Ohio Water Advisory Council for the Department of Natural Resources, Division of Water.

Program Management

At least once each quarter, the Director contacts the Principal Investigator on each research and information transfer project to discuss progress made during the quarter and to discuss the next quarter's plan of activities. At this same meeting budget details are reviewed and discussed, and necessary operating and reporting procedures to the Water Resources's Center and to The Ohio State University Research Foundation's business office are described. Progress Reports or Completion Reports will be prepared for each Project by the Principal Investigators and will be used by the Program Director to prepare the Program Final Report.

All of the investigators are urged to publish the results of their findings in the technical literature of their major disciplines and in other journals that are appropriate to the topic of their research. They are also encouraged and invited to present their findings at the Water Luncheon Seminar that is a part of the technology transfer activities of the Center.

The manuscripts that constitute the project completion reports are first reviewed by the Director of the Water Resources Center. As needed, the Director seeks the advice and council of appropriate state, federal and university scientists for methods of enhancing the value of the technical completion reports to the water--related community in the state and in the region.

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16. Mr. Steve Hindall
    District Chief

UNITED STATES DEPARTMENT OF AGRICULTURE

17. Dr. Norman Fausey
    Agricultural Research Service

TRAINING ACCOMPLISHMENTS

The following tabulation shows, by fields of study and training levels indicated, the numbers of individuals participating in projects that were financed in part with this grant.

Training Category	Training Level				
	Bachlor's Degree	Master's Degree	Ph.D. Degree	Post - Ph. D.	Total
College of Agriculture					
-- Agronomy	1	2			3
College of Engineering					
-- Civil			1		1
-- Environmental	1	1		1	3
College of Biological Sciences					
--Entomology		2			2
--Microbiology		1			1
College of Mathematics and Physical Sciences					
--Geological Sciences			1		1
	2	6	2	1	11